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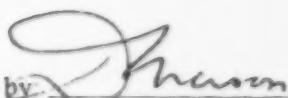
DOR(CAM) RESEARCH NOTE RN-9814

THE EFFECT OF ENDURANCE ON MARITIME HELICOPTER
MISSION SUCCESS: SURFACE

by

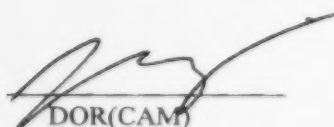
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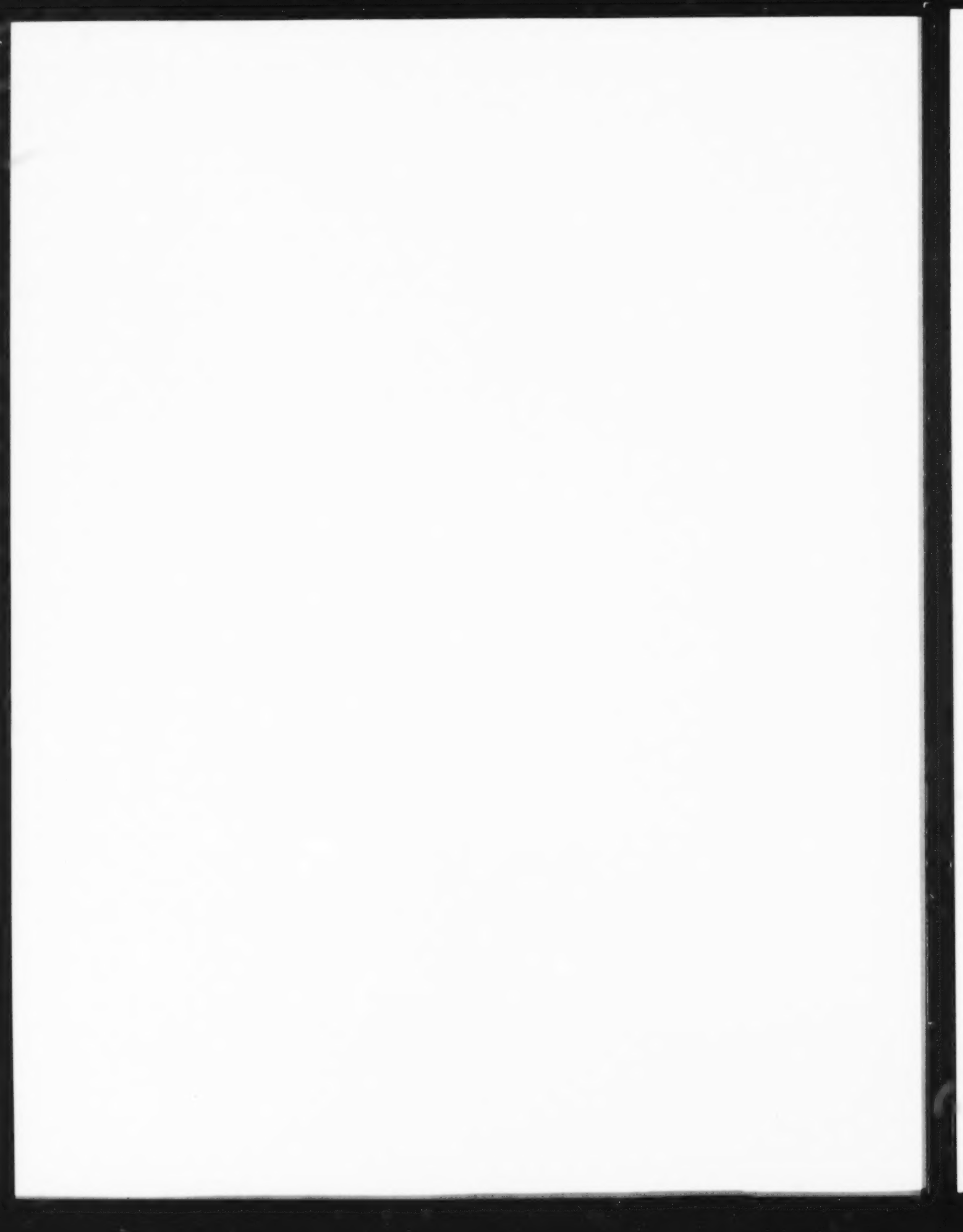


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ABSTRACT

This report looks at the endurance requirement for maritime helicopters. The performance of one, two, two and a half, and three hour helicopters in two patrol scenarios are compared. The results demonstrate a significant difference between the one and two hour helicopters. The difference between two, two and a half, and three hour helicopters is smaller. Due to time constraints, it was not possible to model any scenarios other than simple patrol routines. Thus, the results obtained provide an indication of helicopter performance in simple scenarios, but further modelling is required to incorporate more advanced scenarios.

RÉSUMÉ

Ce rapport examine les exigences d'endurance des hélicoptères de l'aéronavale. On y compare la performance des hélicoptères en utilisant deux scénarios de patrouilles d'une heure, de deux heures, de deux heures et demie et de trois heures. Les résultats montrent une différence sensible entre les hélicoptères patrouillant pendant une heure et deux heures, mais une différence moindre entre ceux qui patrouillent pendant deux heures, deux heures et demie et trois heures. À cause du temps limité, on n'a pu modéliser que de simples patrouilles de routine. Ainsi, les résultats obtenus fournissent une indication de la performance des hélicoptères dans des scénarios simples, mais il faudra procéder à des modélisations plus poussées mettant en jeu des scénarios plus complexes.

TABLE OF CONTENTS

ABSTRACT	i
RÉSUMÉ	i
TABLE OF CONTENTS	ii
INTRODUCTION	1
SIMULATION METHODOLOGY	1
Scenarios	1
Measures of Effectiveness	4
RESULTS	4
Baseline Scenarios	4
Other Factors	7
Theoretical Maximums	13
SUMMARY OF RESULTS	15
RECOMMENDATIONS	16
References	17
Annex A - Helicopter Simulation	A - 1
Simulation Overview	A - 1
Simulation Parameters	A - 3
Simulation Output	A - 4

THE EFFECT OF ENDURANCE ON MARITIME HELICOPTER MISSION SUCCESS: SURFACE

INTRODUCTION

1. The current maritime helicopters in use with ships of the Canadian Navy, the Sea Kings, are near the end of their useful life. The requirements and options for replacement helicopters are now being studied by the Department of National Defence. One of the principal questions being addressed concerns the required endurance for a maritime helicopter. In other words, how long does the helicopter need to be able to stay aloft in order to successfully complete its assigned mission? The result is dependent upon the mission that has been asked of the helicopter. However, some insight into this problem can be gained from looking at a number of typical missions.
2. The Directorate of Aerospace Requirements requested that Operational Research study the impact of helicopter endurance on mission success. A number of scenarios considering the impact of helicopter endurance on subsurface operations are documented separately [reference 1]. This report will analyze two typical surface warfare scenarios. The first scenario is a situation where the task of the helicopter is to classify any vessels entering a channel. The second scenario attempts to classify any vessels transiting through a given area.
3. To analyze these two surface scenarios, a simulation named Helicopter Simulation, or HeloSim for short, was written. This simulation is capable of modeling a number of scenarios, and can easily be adapted to a wider range of situations.

SIMULATION METHODOLOGY

Scenarios

4. The first scenario involves the placement of a ship and helicopter in a channel. Shipping enters this channel on one end, and departs from the other end. It is assumed that all shipping of interest is arriving from one direction, and any vessels entering from the other end is not of interest. The size of this channel is 90 nautical miles (nm) wide and 120 nm long. The ship is placed at the far end of the channel and the helicopter flies a 90 degree pattern at a distance of 60 nm from the ship. The situation is pictured in Figure 1.

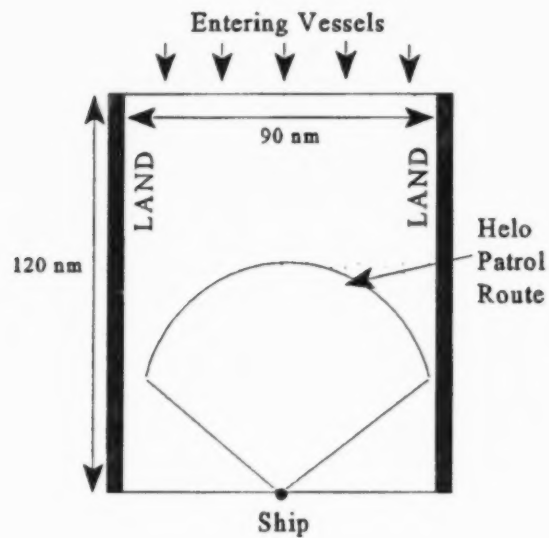


Figure 1: Channel Scenario Area of Interest

5. The second scenario involves placing a ship and helicopter near a coastline. A box 240 nm long and 120 nm wide is being monitored. Vessels transit through the box from either end and depart at the opposite end. The ship is stationed midway along the length of the box, and the helicopter flies a 180 degree pattern at a distance of 60 nm from the ship. This situation is pictured in Figure 2.

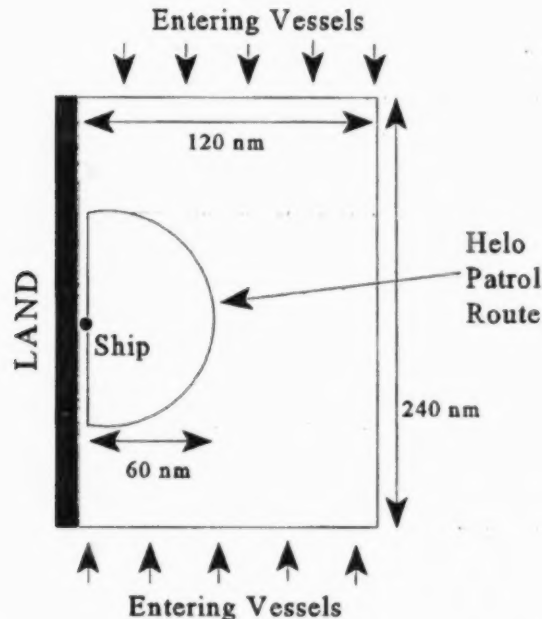


Figure 2: Transit Scenario Area of Interest

6. These parameters and scenarios were agreed to by the project sponsors. Variations of the parameters given below were analyzed as time permitted, and are documented in a later section of this report.

7. The incoming target vessels travel at a constant speed of 10 kts. They enter at a random point, and leave at a random point on the opposite side of the box. While within the box, the vessels travel in a straight line. The vessel density within the box is approximately one vessel per 150 square nm. The naval ship is stationary, and the helicopter travels at 120 kts. It is further assumed that the tracks of all vessels entering the area have already been established through other means, such as advance surveillance, and are known to the ship and the helicopter.

8. The helicopter is equipped with a modern radar which is capable of classifying a vessel by hull type at a distance of 60 nm. In addition, the vessel must be presenting an aspect of no less than 45 degrees. It takes three minutes to classify each vessel.

9. The helicopter conducts its patrol by transiting directly from the ship to the edge of its patrol area 60 nm from the ship. It then flies along a path, maintaining a distance of 60 nm from the ship. When it hits the end of this path, it turns around and flies the path in the opposite direction. This course continues until the endurance limit of the helicopter is reached. The

helicopter then returns to the ship along a straight course. Once at the ship, the helicopter refuels and changes crews, a process which takes 15 minutes. Once refueling is complete, the pattern is repeated. It should be noted that the endurance limit of the helicopter includes the time of both transits. In addition, the helicopter is capable of classifying vessels during both transits as well as during its patrol.

Measures of Effectiveness

10. Two measures of effectiveness (MOEs) are used in each scenario. The first measure gives the percentage of vessels within the full area of interest which have been classified. This indicates the ability of the helicopter to enhance the picture within a given area. The second measure is the percentage of vessels within 80 nm of the ship which have been classified. This indicates the ability to classify any vessels before reaching a point from which the ship could be attacked. Each simulation is run for a time to populate the area of interest with vessels. The ship and helicopter are then introduced, and classification begins. Eventually, a point is reached when the percentage of targets classified for each MOE remains relatively constant. This is termed the steady state probability of classification. For each scenario, a steady state probability is generated for each of the one, two, two and a half, and three hour endurance helicopters.

RESULTS

Baseline Scenarios

11. The classification probabilities for the first scenario are presented in Figures 3 - 6. The MOE values for the baseline scenario are given in Table I.

12. Each graph shows the average number of vessels classified by hour. For instance, in the channel scenario, there are no vessels classified until the 15 hour point when the ship and helicopter begin patrolling. This percentage then climbs steadily until the steady state percentage is reached, at about 21 to 23 hours. The percentage then levels off. The table provides an average steady state over the twenty runs, as well as the standard deviation of the average steady state value. The standard deviations are below 1%, so the results are consistent between runs.

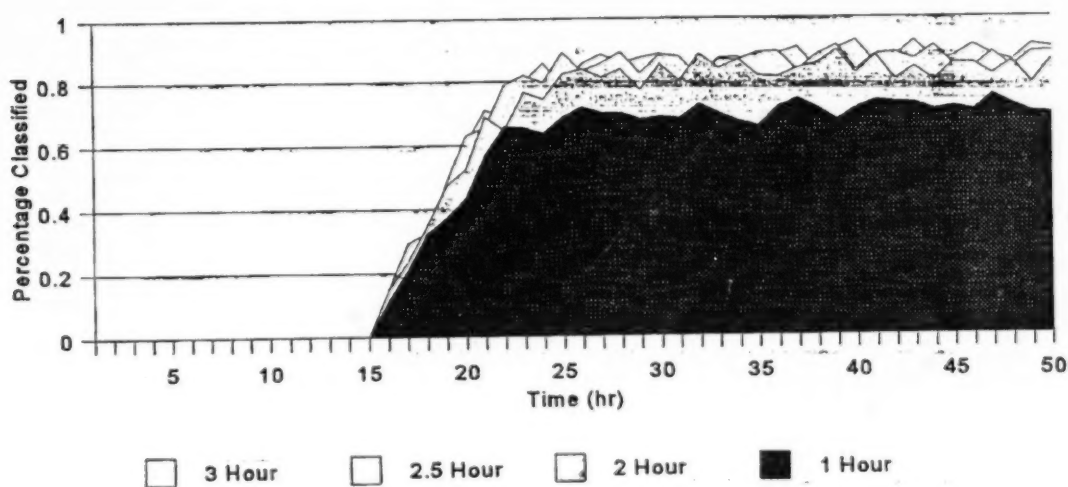


Figure 3: Overall Classification Probability - Baseline Channel Scenario

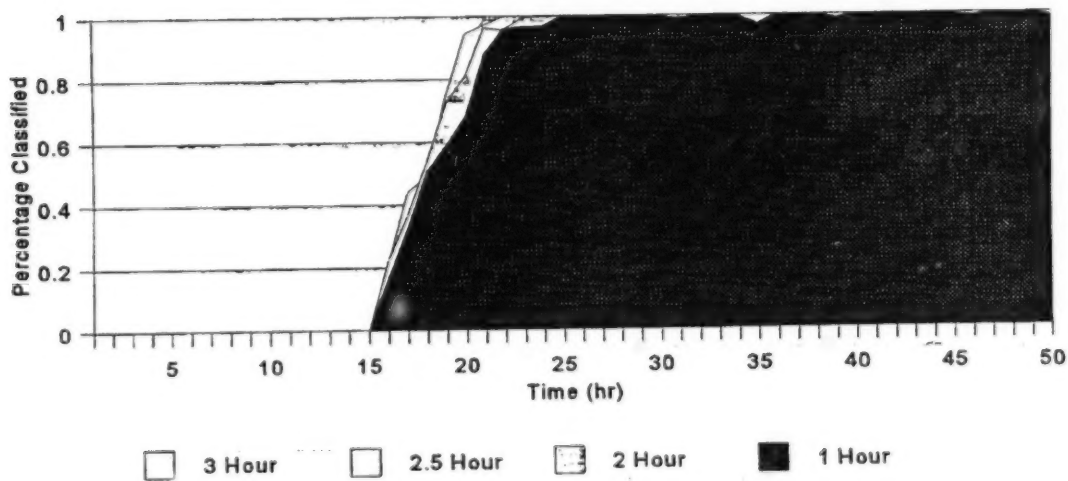


Figure 4: 80nm Classification Probability - Baseline Channel Scenario

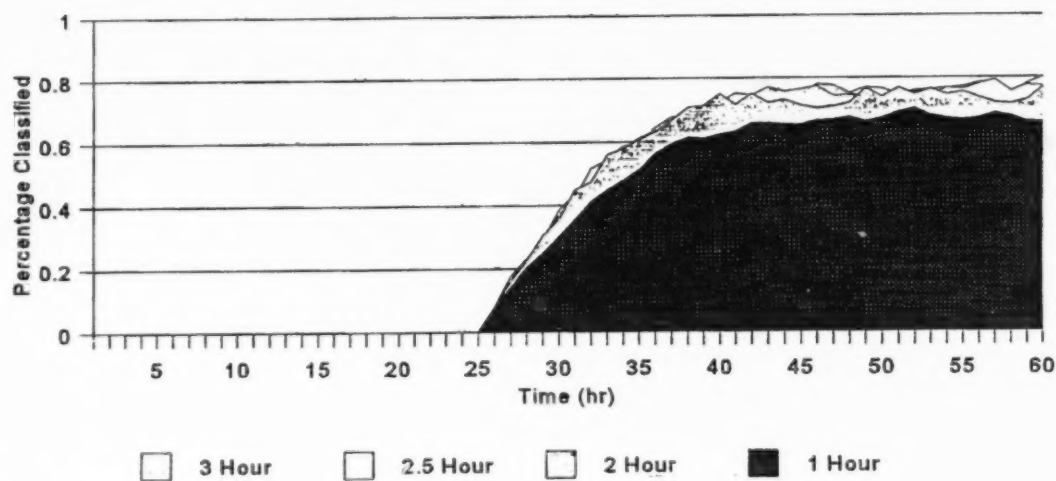


Figure 5: Overall Classification Probability - Baseline Transit Scenario

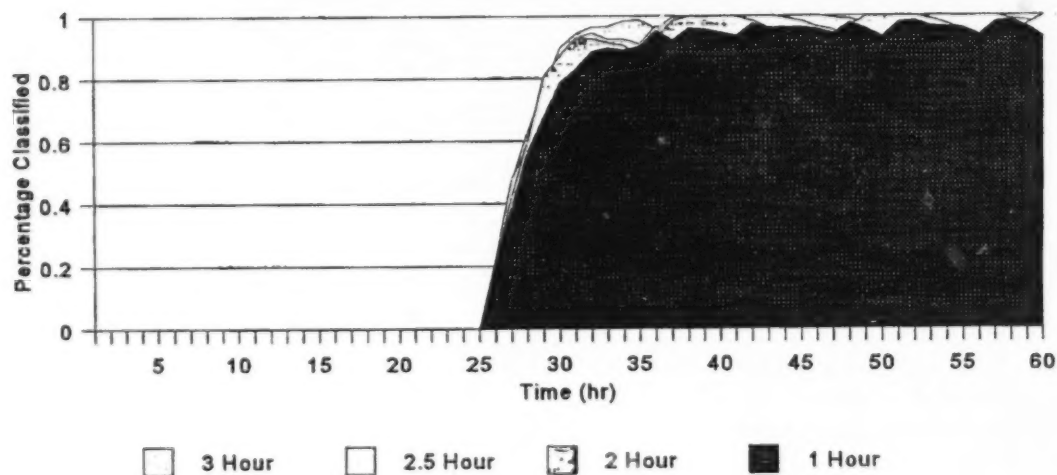


Figure 6: 80nm Classification Probability - Baseline Transit Scenario

13. The steady state probabilities are given below in Table I. As can be seen from the graphs and the table, a helicopter with an endurance of one hour provides a notably reduced level of capability when the overall classification is compared to any of the other helicopters. However,

for the 80 nm detection measure, all the measures are very near 100%, indicating any of the helicopters are capable of performing this task.

	Channel Scenario - 90 degree coverage				Transit Scenario - 180 degree coverage			
	Overall		80 nm		Overall		80 nm	
	Ave	St Dev	Ave	St Dev	Ave	St Dev	Ave	St Dev
Baseline								
1	70.6%	1.30%	99.6%	0.25%	65.1%	1.75%	95.5%	0.85%
2	83.5%	1.11%	100.0%	0.00%	72.5%	1.67%	95.8%	0.77%
2.5	86.8%	0.94%	100.0%	0.00%	73.9%	1.78%	97.5%	0.91%
3	87.2%	0.77%	100.0%	0.00%	74.2%	2.05%	99.3%	0.32%

Table I: Steady State Statistics for Baseline Scenarios

Other Factors

14. In an effort to better understand the impact of each of the variables on the helicopter performance, a number of these variables were varied. Separate runs were conducted to investigate the sensitivity of each of these variables individually. The results are provided in Table II. The factors taken into account are as follows:

- Density of shipping was doubled to one ship per 75 square nm.
- Radar range was reduced to 40 nm.
- 5% of targets require further classification, raising the time of classification for these targets to 10 min. Note that the helicopter does not divert from the regular course during this extended classification time.
- Half of all refuel times are extended to 35 min to simulate instrument and night conditions.
- A 10 min restriction on classifications was imposed before and after ship rendezvous. The helicopter continues on its course during this period, however no classifications are conducted.
- 10% of all classification information is lost each time the helicopter returns to the ship. This is intended to simulate command and control inefficiencies.

	Channel Scenario - 90 degree coverage				Transit Scenario - 180 degree coverage			
	Overall		80 nm		Overall		80 nm	
	Ave	St Dev	Ave	St Dev	Ave	St Dev	Ave	St Dev
1/75 Shipping Density								
1	46.8%	2.82%	72.1%	4.59%	41.8%	1.32%	73.0%	2.88%
2	57.7%	3.53%	87.2%	5.03%	49.0%	1.87%	83.6%	2.79%
2.5	59.7%	4.71%	88.6%	5.58%	50.3%	1.51%	86.4%	2.96%
3	63.8%	4.13%	92.1%	4.65%	50.9%	1.84%	88.3%	2.98%
40 nm Radar Range								
1	53.9%	1.52%	83.2%	1.82%	48.2%	1.54%	80.9%	2.09%
2	65.8%	1.62%	97.1%	1.06%	55.1%	1.74%	86.7%	1.97%
2.5	69.5%	1.38%	99.3%	0.35%	57.9%	1.89%	90.0%	1.66%
3	69.0%	1.16%	99.3%	0.39%	59.8%	2.20%	92.9%	1.86%
5% 10 min Classification								
1	68.7%	2.21%	98.9%	0.51%	62.0%	2.08%	94.4%	1.19%
2	82.2%	1.62%	100.0%	0.00%	71.1%	1.87%	95.7%	0.94%
2.5	85.6%	1.53%	100.0%	0.00%	71.6%	1.83%	97.1%	0.86%
3	85.9%	1.04%	100.0%	0.00%	72.7%	1.44%	99.1%	0.39%
50% 35 min Refuel								
1	67.5%	1.40%	98.2%	0.92%	61.1%	2.53%	92.7%	1.28%
2	82.3%	1.57%	100.0%	0.02%	70.8%	1.54%	94.5%	0.87%
2.5	85.3%	0.67%	100.0%	0.00%	72.1%	1.72%	97.0%	0.84%
3	86.3%	0.92%	100.0%	0.00%	74.0%	2.28%	99.0%	0.31%

	Channel Scenario - 90 degree coverage				Transit Scenario - 180 degree coverage			
	Overall		80 nm		Overall		80 nm	
	Ave	St Dev	Ave	St Dev	Ave	St Dev	Ave	St Dev
20 nm Restriction								
1	65.8%	3.54%	94.7%	4.26%	55.9%	4.45%	89.5%	4.28%
2	83.8%	1.19%	99.9%	0.13%	70.3%	1.79%	94.8%	1.21%
2.5	86.9%	1.04%	100.0%	0.00%	72.9%	1.99%	97.1%	0.94%
3	86.9%	1.09%	100.0%	0.00%	74.9%	2.14%	99.3%	0.28%
10 % Information Loss								
1	48.4%	5.51%	74.4%	8.36%	48.6%	2.38%	81.7%	2.52%
2	80.0%	2.19%	98.0%	0.52%	62.8%	1.66%	91.8%	0.89%
2.5	84.4%	1.22%	98.2%	0.34%	65.6%	2.67%	93.8%	1.02%
3	84.7%	1.12%	98.3%	0.29%	68.3%	2.25%	96.9%	0.75%

Table II: Steady State Statistics for Various Factors

15. None of the factors, when taken in isolation, cause a major difference in steady state probabilities, although the doubling of shipping density, the reduced radar range, and loss of information seem to cause the largest changes. However, the standard deviations are much higher, meaning there is much more variability in the results.

16. When all these factors are incorporated into a single run of the simulation, there is a significant decrease in performance, as depicted in Table III and Figures 7 - 11. As demonstrated from these values, when all factors are considered, it is no longer feasible to classify all vessels within 80 nm with any of the helicopter endurance choices. In fact, only the three hour helicopter is capable of classifying even 25% of all vessels within 80 nm in both scenarios.

17. During the course of this study, it was also noted that the specific tactic used by the helicopter can have a large impact on the percentage classified. For instance, these results use the tactic of classifying vessels closest to the ship first. If this is altered to give priority to vessels that are approaching the 80nm limit, there is a notable change in the results. Although this variation was not explored further due to time constraints, any future studies should look at this factor more closely.

	Channel Scenario - 90 degree coverage				Transit Scenario - 180 degree coverage			
	Overall		80 nm		Overall		80 nm	
	Ave	St Dev	Ave	St Dev	Ave	St Dev	Ave	St Dev
All Factors Included								
1	4.9%	0.58%	7.6%	0.88%	13.5%	1.09%	25.4%	1.90%
2	13.4%	1.03%	20.7%	1.57%	23.9%	1.69%	44.0%	2.87%
2.5	15.0%	0.96%	23.1%	1.60%	27.6%	1.44%	50.6%	2.60%
3	17.3%	1.96%	26.6%	3.17%	30.0%	1.58%	55.3%	3.51%

Table III: Steady State Statistics With All Factors Included

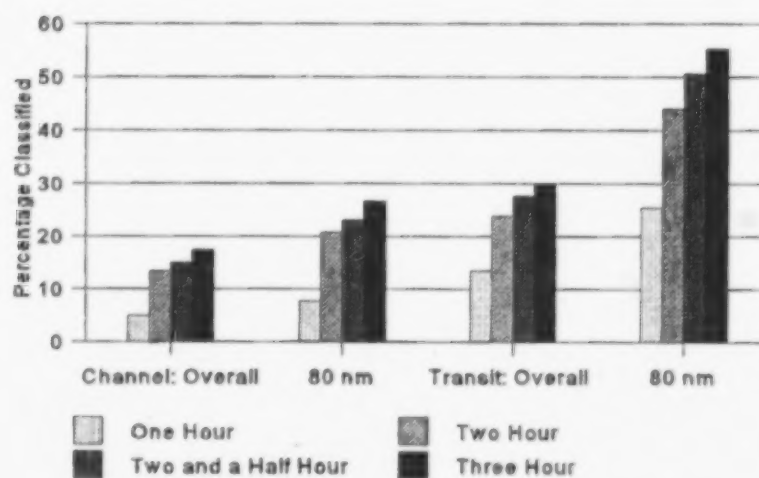


Figure 7: Steady State Averages With All Factors Included

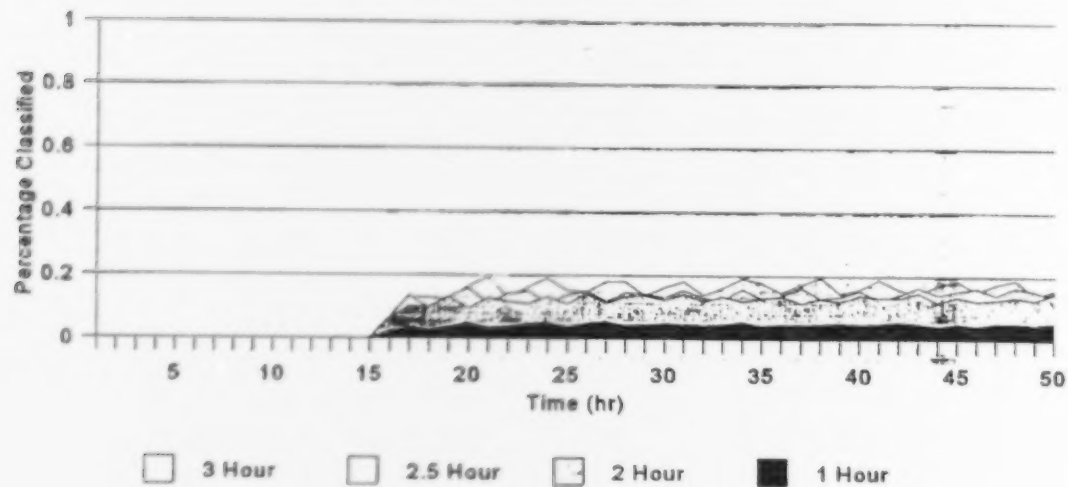


Figure 8: Channel Scenario Overall Classification With All Factors Considered

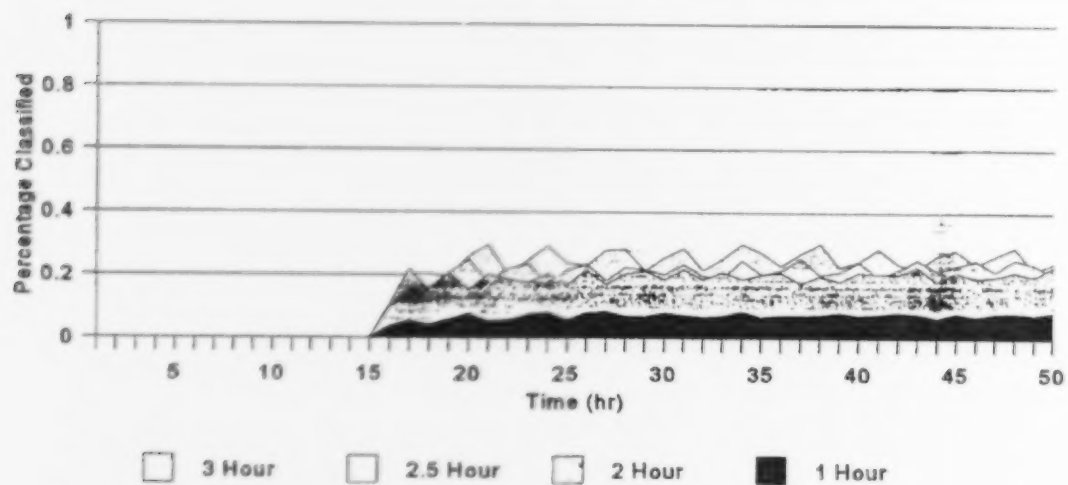


Figure 9: Channel Scenario 80 nm Classification With All Factors Considered

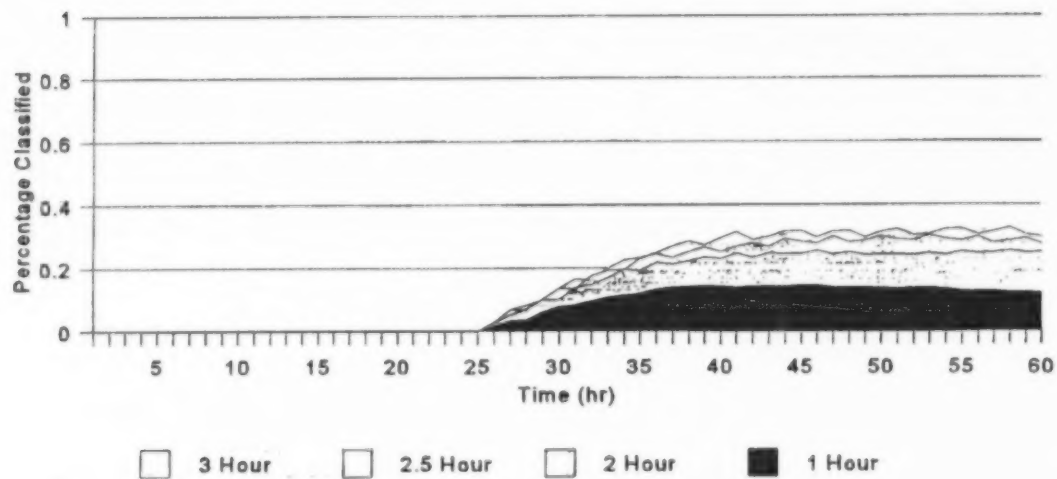


Figure 10: Transit Scenario Overall Classification With All Factors Considered

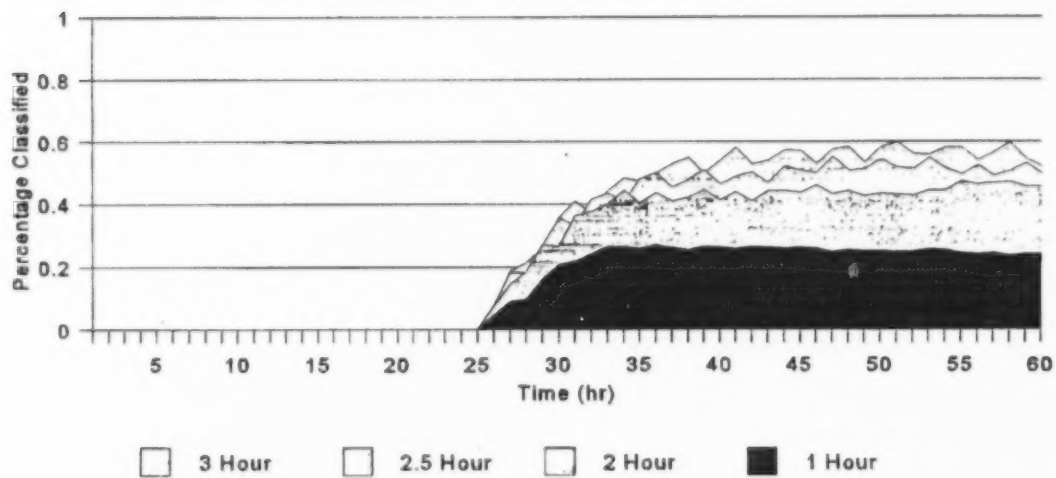


Figure 11: Transit Scenario 80 nm Classification With All Factors Considered

Theoretical Maximums

18. It is possible to calculate a theoretical maximum for the overall classification problem. The theoretical maximum can be expressed as the maximum number of classifications possible per hour, divided by the number of vessels entering the target area per hour.

19. First, consider the baseline scenario. The mean arrival rate for the two scenarios is 6.17 and 7.69 vessels per hour, respectively.

20. Each classification takes three minutes, or 0.05 hours. This gives a maximum classification rate of 20 vessels per hour. However, the helicopter is not classifying vessels constantly because of its requirement to refuel. Thus, the one hour helicopter is airborne for a total of one hour out of every one hour and fifteen minutes, or 80% of the time. Thus, the one hour helicopter is capable of classifying 80% of 20 vessels, or 16 vessels per hour. This is larger than the arrival rates of 6.17 and 7.69 vessels per hour, so it is not surprising that the percentage of classified vessels is very high. The reason the 100% figure is not reached in the simulation is due to the timing and position of arrivals. A number of vessels will arrive in the area while the helicopter is refueling, which are not instantly classified. Also, new arrivals may not be within range of the helicopter immediately. Table IV provides the percentage calculations for all helicopters. The maximum classification rate is given by:

$$\text{Class Rate} = \frac{\text{Active Time} * \text{Airborne Class Rate}}{(\text{Active Time} + \text{Refuel Time})} \div \text{Arrival Rate} \quad (\text{max } 100\%)$$

Endurance	Percentage of Time Active	Class Rate When Airborne	Total Class Rate	Vessel Arrival Rate	Theoretical Maximum Class Rate
Channel Scenario					
1	80%	20/hr	16/hr	6.17/hr	100%
2	89%	20/hr	17.8/hr	6.17/hr	100%
2.5	91%	20/hr	18.2/hr	6.17/hr	100%
3	92%	20/hr	18.4/hr	6.17/hr	100%
Transit Scenario					
1	80%	20/hr	16/hr	7.69/hr	100%
2	89%	20/hr	17.8/hr	7.69/hr	100%
2.5	91%	20/hr	18.2/hr	7.69/hr	100%
3	92%	20/hr	18.4/hr	7.69/hr	100%

Table IV: Theoretical Maximums for Baseline Scenario

21. The situation is a bit more complex for the worst case scenario. Four factors can be worked into this calculation: 20 nm classification restriction (equivalent to 10 min), half of all refuels requiring 35 min, 5% of vessels requiring 10 minute classification, and increased vessel density. Again, using the one hour example, for the baseline scenario, one hour out of one hour and fifteen minutes is spent actively classifying vessels. The 10 min restriction drops this to forty minutes active classifying out of each one hour and fifteen minute period. Half of all refuels requiring 35 minutes reduces the classification time another 10 min on average, so the helicopter is actively classifying vessels for thirty minutes out of each hour and 15 minutes, or 40% of the time. The time required for classification is 0.05 hr for 95% of all vessels, and 0.333 hr for 5% of the vessels. This averages out to 0.064 hr per vessel, or 15.6 vessels per hour. The increased density raises the number of vessels arriving to 12.34 and 15.38 vessels per hour for the channel and transit scenarios respectively. Table V summarizes all these factors and provides the theoretical maximum for each helicopter.

Endurance	Percentage of Time Active	Class Rate When Airborne	Total Class Rate	Vessel Arrival Rate	Theoretical Maximum Class Rate
Channel Scenario					
1	40%	15.6/hr	6.2/hr	12.34/hr	50.6%
2	67%	15.6/hr	10.4/hr	12.34/hr	84.3%
2.5	73%	15.6/hr	11.35/hr	12.34/hr	91.9%
3	77%	15.6/hr	12.0/hr	12.34/hr	97.2%
Transit Scenario					
1	40%	15.6/hr	6.2/hr	15.38/hr	40.6%
2	67%	15.6/hr	10.4/hr	15.38/hr	67.6%
2.5	73%	15.6/hr	11.35/hr	15.38/hr	73.8%
3	77%	15.6/hr	12.0/hr	15.38/hr	78.0%

Table V: Theoretical Maximums for Worst Case Scenario

SUMMARY OF RESULTS

22. The effect of various endurance times of helicopters on two surface surveillance scenarios were investigated through simulation. The results demonstrate a significant improvement of a two hour helicopter over a one hour helicopter, and more modest differences between the two, two and a half, and three hour helicopters.

23. The sensitivity of a number of factors was investigated in order to better understand how each contributes to the results. Most of the factors individually did not have a large impact on the results. However, doubling the vessel density, reducing the radar range, and losing information caused the largest impacts. These three factors in particular should be analyzed in more detail to confirm the accuracy of the input values.

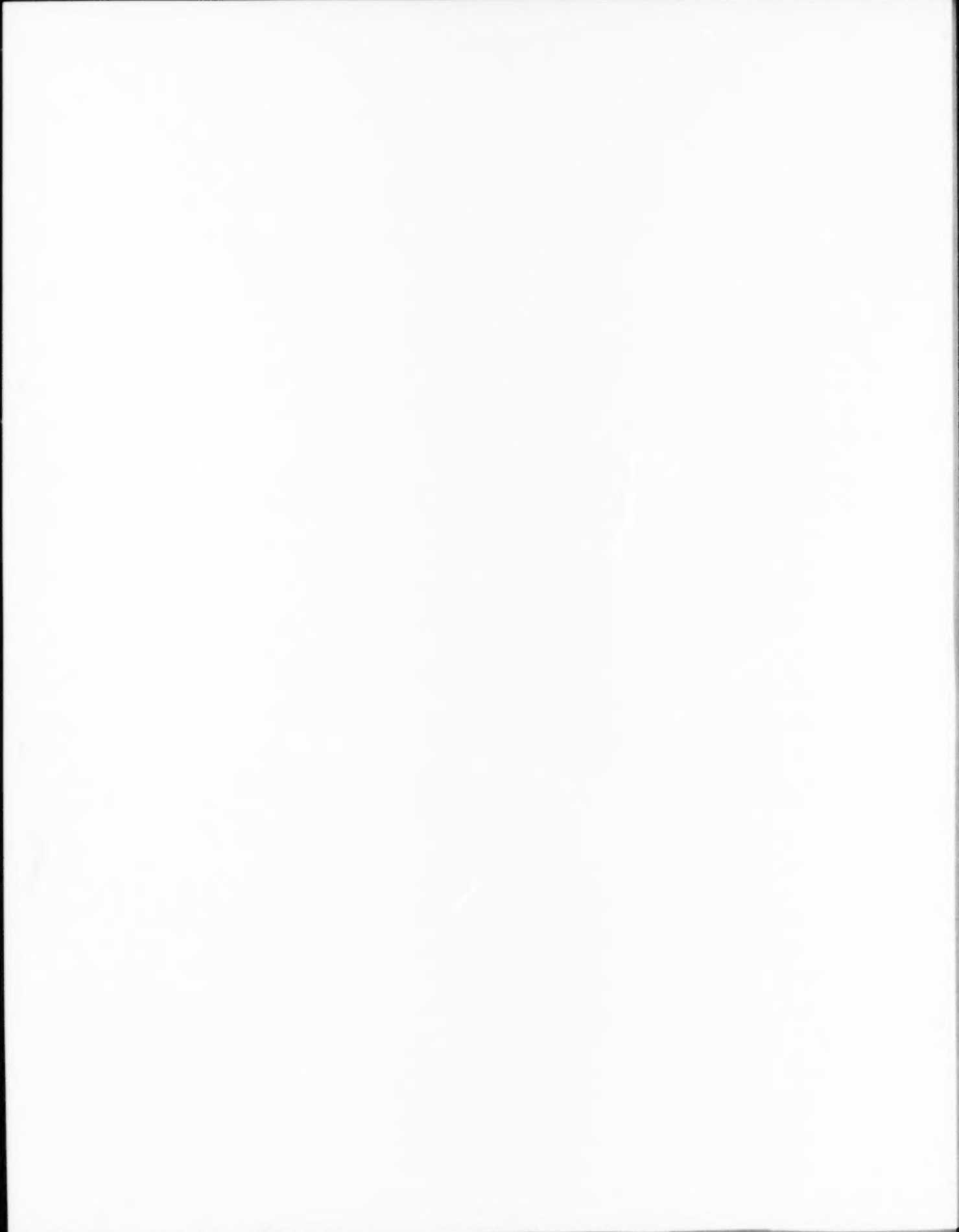
24. When all factors are considered together, a significant reduction in performance results. In this situation, only a three hour helicopter is capable of classifying 25% of all targets within 80 nm of the ship for both scenarios.

RECOMMENDATIONS

25. This model provides an initial understanding of the effect of helicopter endurance on mission success in a surface surveillance role. However, there are limitations associated with this model. As it currently stands, the helicopter is capable of only patrol, and has no reactionary capability. Therefore, the model is capable of simulating the situation up to the point of classification. It cannot yet simulate any actions the helicopter may take against a hostile vessel. Thus, these results must be considered as a preliminary investigation into the effect of helicopter endurance.
26. Varying tactics were not analyzed in this study, however it was noticed that tactics have the potential to greatly impact the results. This should be considered in any further investigations.
27. The targets within this model transit the area on a straight line course and at a constant speed. This may not be representative of a real situation. In particular, a target with hostile intentions may have a different behavior.
28. There are also many other factors which have not been considered. Notable factors which should be considered are the variations between day and night operations, changing meteorological conditions, crew fatigue, and restrictions on the length of time for which helicopters can operate..

References

1. Burton, B., *The Effect of Endurance On Maritime Helicopter Mission Success: ASW*, DND/MORT memorandum, August 1998.



Annex A - Helicopter Simulation

Simulation Overview

1. The Helicopter Simulation (HeloSim) program was written in Microsoft Visual C++ to analyze the effects of helicopter endurance on surface operations. The program simulates a helicopter flying a near-circular patrol pattern centered on a ship. The pattern approximates a circle by flying straight line chords of the circle. The number of chords is specified by the user. Vessels are generated at random intervals and traverse a given area. The helicopter and the ship classify vessels out to a given distance, taking a prescribed amount of time for each classification. The simulation is run for a given number of iterations, and the tracks and classification times for all vessels are output. This output can then be analyzed further to derive the desired measures of effectiveness.

2. There are a number of objects in the simulation that represent real world objects. The principal objects are the CHelicopter and CTarget object. An instance of the former is created to represent the helicopter, and numerous instances of the later are created to represent each of the vessels in the area of interest.

3. The simulation is event-based. An event queue contains a list of chronologically ordered events. Each event changes the state of one or more objects in the simulation, and possibly adds further events to the queue. The principal events and their effects are:

CEventNewTarget:	Create a new vessel. Calculate the time of the next vessel to enter the Area of Interest (AOI), and add another CEventNewTarget event to the event queue at that time. If a sensor (hereafter referred to as an imager) is available on the helicopter, adds a CEventLookForImage event to the event queue.
CEventTransitOut:	Turns on the imager, and adds a CEventLookForImage event to the queue. Calculates the time when the helicopter reaches the station distance, and adds a CEventSetCourse or CEventTransitIn event, as appropriate.
CEventSetCourse:	Adds a CEventLookForImage event to the queue, and adds the next CEventSetCourse or CEventTransitIn event, as appropriate.

CEventTransitIn:	Adds a CEventRefuel event to the queue at the time the helicopter reaches the ship. Adds a CEventImagerNotAvailable event to the queue to turn off the imager at the appropriate time. Adds a CEventLookForImage event.
CEventRefuel:	Adds CEventImagerNotAvailable, CEventTransitOut, and CEventInformationLoss events to the queue.
CEventLookForImage:	Scans all vessels and determines the next vessel to image. Considers range and bearing to determine vessel. Adds a CEventStartImaging event to the queue.
CEventStartImaging:	Marks the imager as busy, and adds a CEventImageComplete event to the queue.
CEventImagerNotAvailable:	Turns off the imager.
CEventImagerBusy:	Marks the imager as busy.
CEventImageComplete:	Marks the indicated vessel as classified. Marks the imager as not busy and adds a CEventLookForImage event to the queue.
CEventInformationLoss:	Marks a specified proportion of all vessels as not classified.

4. Thus, the simulation begins by adding a CEventTransitOut event, with a specified time stamp, and a CEventNewTarget event to the queue. The simulation then proceeds sequentially with the queue. There are only two members of the queue, so it processes the first event, CEventNewTarget. This creates a new vessel, and adds another CEventNewTarget event to the list. A number of these events are processed until the CEventTransitOut event is encountered.

5. When this event is encountered, the initial helicopter course is entered, and a CEventNewCourse event is created with the appropriate time stamp. A CEventLookForImage event is also immediately entered in the queue. When this event is processed, the course of the helicopter is compared to the course of each of the vessels in turn. The first vessel to be within range of the imaging radar is selected, and a CEventStartImaging event is created with the appropriate time stamp. If more than one vessel is within range, the one closest to the ship is selected.

6. When the CEventStartImaging event is encountered, the time required to image the vessel is calculated, and a CEventImageComplete event is entered with the appropriate time stamp. When this event is encountered, the vessel is marked as classified, and a CEventLookForImage event is immediately created. The cycle then begins again.

7. Eventually, the CEventNewCourse event will be encountered. This event calculates the next leg of the course for the helicopter. A CEventNewCourse event or a CEventTransitIn event are entered with a time stamp to represent the end of the current leg. A CEventLookForImage event is immediately entered, and the imaging cycle starts again.

8. When the CEventTransitIn event is encountered, a course is calculated and entered to immediately return to the ship. A CEventRefuel event is entered with the appropriate time stamp to represent the turnover time for the helicopter before being able to resume the mission. When the CEventRefuel event is processed, a CEventTransitOut event is added to the queue, and the entire routine starts anew.

Simulation Parameters

9. The following parameters can be set by the user:

Number of Stationary Targets:	Creates a specified number of targets which are stationary throughout the length of the simulation.
Time Between Arrivals:	The average time between vessels arriving in the area of interest, given in hours.
Speed of Vessels:	Speed of vessels transiting the area of interest.
Radar Range:	Range of the radar used for classification.
Classification Time:	Normal time in hours required for each vessel to be classified.
High Interest Percentage:	Percentage of vessels which require a longer classification time.
High Interest Time:	Time in hours required to complete a longer classification of a vessel.
Speed On Station:	Helicopter speed on station.
Transit Speed:	Helicopter speed while transiting to or from station.
EMCON:	Time in hours of radar emission restriction.
Refuel Time (50%):	Two entries for the length of time required to refuel and turn around the helicopter.

Endurance:	Helicopter endurance time in hours.
Station Distance:	Distance from the ship of the helicopter station.
Run Time:	Run time of the simulation.
Start Time:	Time at which helicopter operations begin.
Number of Segments:	Number of segments used to approximate the circle. A higher number approximates a circle better, but requires more time to run the simulation.
Starting Segment:	Segment at which the helicopter begins patrolling.
Coverage Degrees:	Length of arc in degrees which is to be covered by the helicopter.
Start Coverage Degree:	Position of counter-clockwise extent of helicopter coverage. Straight north is 0 degrees.
Information Loss:	Percentage of classifications lost when the helicopter return to the ship.

Simulation Output

10. The output of the simulation consists of all vessel tracks. The track information is written to a file specified by the user. Each line in the output represents one vessel. Each line starts with the X- and Y-coordinates of the start point of the vessel. The next two values are the X- and Y-velocity of the vessel. The next two values are the time the vessel enters the area of interest, and the time the vessel leaves the area of interest.

11. The previous information is recorded for all vessels. Following the required six values are optional pairs of numbers representing the time the vessel is classified and the time the vessel classification is lost. A vessel may be classified and lost many times, so there could be any number of values.

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This report looks at the endurance requirement for maritime helicopters. The performance of one, two, two and a half, and three hour helicopters in two patrol scenarios are compared. The results demonstrate a significant difference between the one and two hour helicopters. The difference between two, two and a half, and three hour helicopters is smaller. Due to time constraints, it was not possible to model any scenarios other than simple patrol routines. Thus, the results obtained provide an indication of helicopter performance in simple scenarios, but further modelling is required to incorporate more advanced scenarios.

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